[Proc. Roy. Soc. Victoria, 26 (N.S.), Pt. II., 1914.]

Art. XXII.—*On the Geology and Petrology of the District between Lilydale and Mount Dandenong.*

By MORRIS MORRIS, M.Sc.

(Formerly Kernot Research Scholar, and Caroline Kay Scholar in Geology, University of Melbourne.)

(With Plates XXIX., XXX. and XXXI.)

[Read 13th November, 1913.]

Contents.

I.—Introduction.

The area to be described lies about 23 miles east of Melbourne. It is a rectangular block of some 36 square miles, with its southern base line passing east and west across the Trig Station on Mt. Dande-

nong, and its northern boundary running in a similar direction about one mile north of Lilydale. Laterally, it reaches from about Mooroolbark in the west to near Wandin in the east.

From Mt. Dandenong one looks eastward across the Woori-Yallock basin to the closely related mountains of Healesville and Warburton, northwards to the Dividing Range, beyond the alluvial flats of the Yarra, and westwards and southwards across a dissected plain, sloping towards the coast line.

It was found necessary to extend the mapping in various directions beyond the limits above defined, but such extensions are omitted, and will only be referred to when necessary to illustrate features that already appear in the circumscribed area.

II.—Previous Work.

In 1856 Sir A. R. C. Selwyn (1) made a brief description of Cave Hill, near Lilydale, where he found "the entrance to a cave 120 feet deep," which eventually became the site of Mr. Mitchell's limestone quarry.

In 1892-3 Rev. A. W. Cresswell, M.A. (3, 4), wrote two papers, both of which deal almost solely with the fossiliferous contents of the Cave Hill limestones.

It was not till six years later that any work was commenced on the stratigraphy of the district. In 1899 the late V. R. Stirling (8) published a brief description, and made a map, of Cave Hill and of a narrow strip of the district contiguous with it eastward as far as Lilydale, and westward across the railway line, where it embraces a small residual plateau capped with basalt. He failed, however, to recognise the important series of igneous rocks which flank Cave Hill on the east, and which, together with those of an earlier series, form the surface rock of Lilydale. These he called metamorphosed Silurian strata, being betrayed by a most deceptive resemblance which they bear to an indurated shale.

These two igneous series possibly belong to the opening movements of a great cycle of igneous activity, which culminated in the piling up of the Dandenong Rages. The remains of this system, which occupy the greater part of the area represented on the map, form the most conspicuous feature of the district, and will be the chief subject of this paper.

During 1910 I mapped and described the area contained in a triangle, whose apices are Mooroolbark, Lilydale and Evelyn. The present map and paper are an extension of these earlier unpublished observations.

Stratigraphical Classification.—The rocks of the district fall into four groups:—

1. A sedimentary series of the Upper Silurian epoch.
2. An igneous series of the Later Palaeozoic (?) period.
3. An igneous series of the Early Tertiary (?) period.
4. An alluvial series, Recent.

III.—The Upper Silurian Sediments.

Prof. Gregory (10) subdivided the Silurian of Victoria into a Lower or Melbournian Series, and an Upper or Yeringian Series. The Lilydale Silurians belong to, and form the type deposits of, the Upper Silurian, which were called Yeringian, after the parish where Lilydale is situated.

Between Melbourne and Warburton, the Silurians are apparently folded into two great synclines. In one of these, called by Prof. Gregory, "the Lilydale Synclinal," the Upper Silurians of the area under review have been preserved. This great syncline extends from the Warrandyte anticline on the west, through Lilydale and Yering, to the Woori Yallock basin on the east.

Lithological Characters.—The Yeringians are marine deposits, whose character varies with increasing distance from the old Silurian shore line. They vary between the conglomerates of Cave Hill, the sandstones and quartzites of Gruyere, the limestones of Mr. Mitchell's quarry, and the mudstones and shales of Mooroolbark and other places.

The Limestones.—There are two outcrops of limestone at Cave Hill, the one an occurrence about 80 yards square in Mr. Mitchell's quarry, the other a small outcrop about 4 feet square in the railway cutting, about 300 yards south of the quarry. The well-formed strata of the quarry dip east (8) at about 50 deg., and strike a few degrees east of north. Their eastern limit is determined by a thick bed of quartzite, which overlies them conformably. Their western limit is concealed under an overburden of basalt. (Plate XXX., Fig. 1.)

This limestone formation has been incompletely described by Sir A. R. C. Selwyn (1), R. A. F. Murray (7), A. W. Cresswell (2, 3, 4), and V. R. Stirling (8). Its abundant fossiliferous contents have been investigated by Sir F. McCoy, R. Ethridge, jun.; G. B. Pritchard, F. Chapman, and A. W. Cresswell.

Sir F. McCoy referred them to the Upper Silurian on palæontological evidence (7).

Similar limestone formations occur in the Upper Silurian at Waratah Bay, Tyers River, Buchan River, Thomson River (between Walhalla and Toongabbie), Loyola, and Delatite River near Mansfield.

According to Murray (7) all these are lithologically similar, being in each case crystalline rocks, and full of crinoid stems, replaced by $CaCO_3$. "The limestones are found in some cases to be undoubted lenticular intercalations."

Macroscopically examined, the Cave Hill limestone is a dark bluish gray, compact, crystalline, and medium grained rock. Fresh specimens do not readily exhibit their organic remains, but in weathered specimens, Hydrozoa, represented mainly by Favosites grandipora and Heliolites, and Brachiopoda, represented especially by Atrypa reticularis, occur in some cases perhaps as abundantly as Crinoidea.

Microscopic Examination.—The thin slices examined are crowded with fossil remains of all sizes, most of which appear to belong to the Hydrozoa. Their outlines are broad and dark, probably owing to impurities, but the interior is generally occupied by calcite. The whole is cemented together by interstitial calcite. A grain of quartz appears occasionally. Dolomite is rather common. It occurs in small rusty-coloured patches, and is identified by staining.

The signs of thermal metamorphism are entirely absent. The rock owes its crystalline structure to metasomatism chiefly, and possibly in some degree to stresses set up during the folding of the beds.

The Cave Hill Quartzites and Conglomerates.—This bed, which is not less than 70 feet thick, overlies the limestones of Mr. Mitchell's quarry conformably on the east, and forms their upper limit. Owing to its superior resistance to the forces of erosion, it is a prominent surface feature, forming the eastern flank of Cave Hill, and a neighbouring eminence, immediately south of Cave Hill.

At Cave Hill, the bed is a quartzite. Going south, it gradually develops into a loosely consolidated conglomerate, consisting of quartz pebbles set in a matrix of granular quartz. The pebbles are easily separated from the matrix.

Under the microscope, the quartzite is seen to consist of rounded grains of quartz chiefly, and a little felspar, most of which show nodulose extinction. The large interstices are often occupied by a fine matrix, some of which appears to have been produced in situ by the mylonitization of the grains. Much of the matrix seems to be a silicious cement, which is frequently ferruginous. The

mosaic structure of the thermal metamorphism is entirely absent It is therefore evident that consolidation here, as in the limestone has been due chiefly to metasomatism, and possibly also in some degree to dynamic metamorphism during the folding of the beds. This result is interesting inasmuch as thermal metamorphism is the only process which Murray (7) and Stirling (8) suggested to account for their alteration. The only instance of thermal metamorphism of the Silurian, that I have seen in the district, occurs along the eastern shoulder of the Dandenong Range, where the sedimentaries have been converted into a hornfels.

South of Cave Hill the quartzites increase their dimensions gradually, spreading westwards, and giving place as they do so to a fine-grained sandstone. (See Fig. 6, Plate XXX.)

The limestone boulder in the railway cutting is flanked immediately on the east by these easterly dipping sandstones. Assuming that it is *in situ*, this boulder appears to form part of the thin end of a lenticular limestone formation, related to the Cave Hill strata as per Fig. 6. In this case, assuming the absence of faulting, the western limit of the Cave Hill formation lies as far to the west of the quarry as the railway line, and possibly beyond it.

The colonies of marine organisms, which formed the limestones, perished through the accumulation of sands, initiated probably by a movement of uplift. But the same sands which killed them have preserved their remains. Defended behind this quartzite rampart, and sheltered by a roof of basalt, the limestones have escaped destruction.

The prevalence of other quartzite and sandstone ridges to the north-east, in Gruyere, where they rise abruptly above the flats of the Yarra, together with the occasional presence of conglomerate, probably indicates the inception and progress of those movements of elevation, which caused the last retreat of the Silurian sea.

The disposition of the Gruyere ridges appears to be causally related to the strike and folding of the beds. (See Fig 5, Plate XXX.) They occur in two pairs, and each pair may be arranged along a straight line, parallel to the strike of the beds, and therefore to each other. Both lines strike 16 degrees east of north. (This easterly divergence is matched between Lilydale and Coldstream by a strike of 47 degrees to 53 degrees east of north, thus indicating a strong lateral easterly thrust in the Silurians north of Lilydale. Just east of Evelyn the strike diverges 38 degrees east of north.) The eastern pair both have a crescentic shape, with the crescent opening northwards. Of the western pair the northern one is also

in the form of a crescent, but it opens to the south. These phenomena may be explained on the hypothesis, that the eastern pair lie along an anticlinal axis, and the western pair along a synclinal axis, the fold in both cases pitching south.

Further, it is owing mainly to these resistant ridges that the Yarra has had to take such a long bend to the north after leaving the course set for it in the Warburton Gorge.

IV.—Late Palaeozoic Igneous System.

The great revival of igneous activity which occurred at many centres of Victoria in the late Palaeozoic, and produced, among other formations, the Snowy River Porphyries, the Strathbogies, and Mt. Macedon, developed in the district under review, into a cycle of three phases—a volcanic phase, including probably five series (of which the last three formed the Dandenong Ranges), a plutonic phase, and a hypabyssal phase.

Distribution.—The whole system has the form of a rough triangle, with its broken apex between Lilydale and Wandin. From this place, it extends south for twenty miles to the Gippsland railway line, near to which its broad base of about 15 miles is spread out between Dandenong and Pakenham. A line connecting Emerald with a point two miles south of Ferntree Gully divides this triangle into two parts, and, roughly speaking, the southern part contains the plutonic outcrops, and the northern part the volcanic rocks of the system.

This map and paper is chiefly occupied with the northern extremity of the volcanic series, and as this area, though small, contains all the series of the system, it therefore supplies material for the description of the whole cycle.

Relation to the Silurians.—The part of the system shown on the map is girdled on three sides by the Silurians, of which those on the west dip east, and those on the east dip west. The upturned edges of the Silurians dipping at a high angle may be seen almost in contact with the overlying igneous rocks at a quarry about $1\frac{1}{4}$ miles from Lilydale, along the railway line to Coldstream, and also at a small quarry about 200 yards north-east of Cave Hill. The igneous rocks therefore occupy a denuded syncline.

A.—The Volcanic Phase.

The volcanic rocks are represented by five series. Using Hatch's classification, but with reasonable elasticity, these series are as follows, naming them in the order of extrusion :—

a The Lower Toscanite series.
b The Upper Toscanite series.
c The Lower Dacite series (passing up into a fragmental series).
d The Middle Dacite series.
e The Upper or Hypersthene Dacite series.

For the sake of economy in space, when referring to these series, the above letters—*a*, *b*, *c*, *d*, and *e* are frequently used instead of giving the whole name.

a. The Lower Toscanite Series.

This is a complex series of lavas alternating with laminated formations, which ought probably to be regarded as a banded effusive rock.

Field relations. The series forms a rough arc reaching from Lilydale to within a mile of Wandin, bounded on its north and convex side by the alluvium and Silurians of the Yarra basin, and embracing on its concave side the next series (*b*) in the system. It is best developed on the west limb, where it forms the surface rock of the greater part of Lilydale, and also the prominent ridges just outside of the town on the north-east. It also occurs in small patches along the western edge of the system, even as far south as Montrose. There are two small patches of it east of Mooroolbark, one an inlier in the next series (*b*), and the other an outlier on the Silurians. It, therefore, had a wide distribution. Owing, probably, to denudation, it becomes less conspicuous going east from Lilydale, and occurs there only in discontinuous areas.

Stratigraphical Relationship.—(i.) Its wide distribution, and its invariable association with series *b*, show that these two adjacent series were co-extensive over a large area. (ii.) The chemical evidence show that *a* and *b* are inseparable. The one must, therefore, lie immediately, either above or below the other. (iii.) *a* is in many cases immediately underlain by the Silurians, and *b* is visibly in one place, and over a large area may be proved to be, overlain immediately by the series *c*. Therefore, since *a* cannot lie above *b*, it must be below it. This conclusion is further supported by the arrangement of vesicles in series *a*, in the railway cutting behind Lilydale, so as if continued to dip beneath the adjacent series, *b*. This conclusion is corroborated also by the apparent superposition of a high conical hill of series *b* on a low platform of series *a*, which flanks the former on the north and west.

Taking this evidence together, it seems safe to conclude that *a* is older than *b*.

Petrological Characters.—In the field, the members of this series appear so heterogeneous as to seem capable of further subdivision. But the microscopic evidence shows that they belong to one family. They agree in bearing phenocrysts of felspar, and a ground mass full of orthoclase, but with relatively little quartz. They differ in the structure of the ground mass, and in the nature and amount of ferro-magnesian minerals present.

Three types have been selected for description, (1) from the base of the series, (2) from the middle (3) from the top.

1. The Basal Member.—Specimen from quarry, allot. 24, north end. A hard, brittle, bluish-gray streaky rock, fine grained, with occasional phenocrysts of felspar.

Under the miscroscope, it is found that idiomorphic phenocrysts of plagioclase (probably oligoclase) are sparingly developed, and arranged parallel to the flow structures of the ground mass, which consists chiefly of felspar microlites, set in a sparse cryptocrystalline matrix. These microlites are of two kinds—(a) very minute laths of plagioclase (probably oligoclase), (b) larger and rhombic or square-shaped crystals of orthoclase. Orthoclase is greatly in excess of plagioclase in the ground mass, and apparently of the phenocrysts also. This is due to the high percentage of alkalis present (viz., 6.98 per cent.). Of CaO there is 1.95 per cent., most of which has combined with CO_2 without being removed, This is clear from the presence of 1.80 per cent. of CaO in the next series (*b*), which is nearly identical in chemical composition, and contains no CO_2. Iron oxide in the rectangular grains occur sparingly. Sericitic material and some secondary quartz leached from the matrix, occupy original vesicles or planes of weakness, and give the rock a streaky appearance. The specific gravity of this rock is 2.489. The chemical analysis is given later.

Its *industrial value* as metal for roads and ballasts is due to its hardness, to its brittleness rendering it easy of preparation, and to the absence of unstable minerals. It is extensively quarried for this purpose.

2. The Middle Member.—Specimen from railway cutting behind Lilydale. Like the basal member, except that it is not brittle, but, on the contrary, exceedingly tough, and also much more vesicular and streaky.

Phenocrysts of plagioclase, orthoclase (subordinate), and biotite in large flakes, are present, the latter being much decomposed, and the alteration products fill the original steam pores. One small phenocryst was found with the colour, pleochroism, cleavage, extinc-

tion, and polarisation characters of hypersthene. Iron oxide, apatite, and zircons occur as accessories. The ground mass is like that of the basal member, except that the orthoclase is not idiomorphic, but allotriomorphic. It envelopes the laths of plagioclase, and occupies the interstitial spaces so continuously that there is but little glassy base present. As the orthoclase has crystallised from various centres, it produces an extinction effect resembling strain shadows. Pronounced fluxional arrangement of laths and phenocrysts occurs. Granular chlorite and biotite are present, and also a little quartz.

The spec. grav. is 2.62 (for least altered specimens).

It forms the surface rock of the chief part of Lilydale, and also constitutes a big part of the hills, which overlook the town on the north-east.

3. Upper Member.—Specimen from Allot. 24, south end. A gray slate-coloured rock, fine grained, hard and tough, showing felspar phenocrysts with fluxional arrangement. Idiomorphic phenocrysts of plagioclase (probably labradorite) are common; apatite, zircon, and iron oxide rather frequent. The ground mass is like that of the middle member, and consists of microlites (probably oligoclase), surrounded by optically continuous patches of orthoclase. Elongated streaky areas of sericitic material abundant, and this, together with secondary quartz, occupies what seem to be original vesicles, or planes of weakness.

Spec. grav. 2.65.

Chemical and Mineralogical Characteristics.—The three members of the series agree in the relatively small amount of primary quartz present, considering the high SiO_2 contents (68 per cent.), and also in the prevalence of orthoclase in the ground mass, accounting for the high alkali contents (6.98 per cent.). They differ chiefly in the structure of the ground mass. In the basal member, the orthoclase formed regular-shaped crystals, and these set in a cryptocrystalline base, give the rock its brittle character. In the other members, the orthoclase crystallised more extensively, the patches from various centres moulding themselves on one another, and occupying the interstitial spaces so fully that but little base remains. These rocks are therefore very tough.

The abundance of orthoclase, and the subordinate quantity of quartz, in the ground mass of this series, has been effected by the assistance of mineralisers, especially water, of whose plentiful supply the vesicles bear evidence. This is further discussed below.

The high percentage of silica (68 per cent.), and of alkalis (6.98 per cent.), constitute this rock a toscanite, according to Hatch's classification.

The Geological Map.—This series is coloured Silurian on Selwyn's sketch map, and on the geological map of Victoria, having been regarded as altered sediments by Murray (7) and Stirling (8). The latter coloured this and the succeeding series (*b*) Silurian in his map of Lilydale, and shows in his section a hypothetical trappean mass under the township to account for their alteration.

b. The Upper Toscanite Series.

The visible distribution of this series resembles a shepherd's crook, the crook bending east at Lilydale, and enclosing the succeeding series of the system. From Lilydale, where it forms part of the surface rock, it runs south for seven miles, forming a narrow strip between the Silurians and the Lower Dacite series (*c*).

Petrological Character.—The whole series is characteristically homogeneous. The only variations are due to the alteration of effusive and explosive phases. The explosive types, varying from lapilli to agglomerate, are generally preserved in the form of hills, and some of these are probably close to, if not on the sites of, the volcanic vents. They are well developed opposite the Salvation Army farm, near Bayswater, and near Montrose. In the extreme northern part of its distribution, these fragmental types occur almost continuously over a large area, and they appear to become increasingly coarse towards a pair of high conical hills as centre, where the agglomerate contains fragments as big as a man's head. I, therefore, regard these two hills as denuded necks of Devonian toscanite volcanoes, and have marked them as such on the map.

The following is a description of the normal effusive rock when fresh :—

Macroscopic.—A blue-black, non-vesicular, compact, exceedingly fine-grained, brittle rock, intricately traversed by joint planes, and showing rather sparingly lustrous phenocrysts of felspar.

Microscopic.—Phenocrysts consist of plagioclase, some of which is determined to be oligoclase and andesine, idiomorphic, but sometimes corroded; glassy sanidine subordinate; biotite occasionally in small flakes; apatite, zircon, rutile, and rectangular crystals of iron oxide. The ground mass is microcrystalline. It contains a

little quartz and a good deal of felspar microlites, giving extinction angles from 0 deg. for the majority, up to 30 deg. for the rest. (Some of the former may be orthoclase.) Flow-structure is slightly indicated by the general parallel arrrangements of microlites and phenocrysts. Granular green slightly altered biotite is abundant.

Spec. grav. 2.66.

Owing probably to the easy passage offered to water along its intricate network of joint planes, the whole series has been subjected to such extensive alteration that it resembles more a whitish baked shale than an igneous rock. Previous writers (R. A. F. Murray (7) and V. R. Stirling (8)) have regarded it as metamorphosed Silurian. In this extremely altered condition, the felspar phenocrysts have disappeared, leaving rectangular cavities. The ground mass is felsitic, but shows much granular secondary quartz, veined by strings of the same mineral. In the freshest specimens the specific gravity is 2.66; in the altered type, it is 2.37, a loss of nearly 11 per cent.

The altered type of this series provides the chief road metal of the district, a use for which it is well adapted. Being rather brittle, it is easily prepared, and. while providing binding material, its condition as an ultimate decomposition product tends to prohibit the formation of dust and mud.

Chemical and Mineralogical Composition.—The chemical analysis of a member of this series is given later, and is practically identical with that of the preceding series (*a*). Silica (69.9 per cent.) and alkalis (6.9 per cent.) are both high, constituting the rock a toscanite like its predecessor. But, unlike its predecessor, the ground mass is abundant. It is glassy or microcrystalline, and it contains but little orthoclase.

Comparison of the toscanites (*a and b*).—The first two series, then, are toscanites. In each case quartz never appear in phenocrysts, and only to a comparatively small extent in the ground mass. But although their chemical composition is practically the same, there is a fundamental mineralogical difference between them, which prevents their being called facies of the same series. This difference, which as a rule appears so plainly on comparing the hand specimens, inheres in the ground mass. In the first series (*a*), the ground mass is often practically holocrystalline, owing to the abundance of orthoclase; in the second series (*b*), it is often almost non-crystalline, and orthoclase seems sparse or absent while minute flakes of biotite are frequent. There can be no doubt that this difference was due to the fact that mineralisers, chiefly

water, were abundant in the first series (a), and almost absent from series b. Steam vesicles are often prevalent in the first series; they are entirely absent from the second.

Unlike most of the plagioclase felspars, orthoclase, and also quartz, cannot be produced artificially from simple fusion, except with the aid of water or other mineralisers. The water functions chemically as a catalyser, and physically as a flux, reducing the viscosity of the magma, and lowering the freezing points of its constituent minerals. It is well known that a simple fusion of the constituents of orthoclase becomes extremely viscous in the neighbourhood of its melting point. Harker (19) remarks, "It is easy to believe that the presence of a small amount of water may so reduce such viscosity as to enable the alkali felspar to crystallise freely."

We may, therefore, conclude that the presence of water in the first magma (a), enabled orthoclase to crystallise freely, while its absence from the second magma (b) restricted the process. Since the mineralisers must be regarded as an integral part of the rock magma, the reason for separating the first two series is obvious.

Evidence of Foliation.—In the quarry of Allot. 22c on the west limb of the system, series b acquires a very sight banded character, which is only discernible on a polished surface. This feature, in an accentuated form, is quite common in the lower series (a).

Specimens of series a from Allot. 23^a show two sets of banding intersecting at a very small angle. In thin sections, the bands are seen to be occupied by the ordinary ground mass, and by abundant grains of a sericitic mineral, which is clearly secondary. The phenocrysts, and the few microlites which occur, are arranged with their long axes approximately parallel to the banding. The phenocrysts show scarcely any sign of strain shadows; therefore, the banding was not produced by earth movements after consolidation. It must be explained, then, either as the bedding planes of a tuff or as foliation due to movement during consolidation. The parallel arrangement of the microlites and phenocrysts with reference to the banding, and the presence of *two* sets of bands, offer support to the latter hypothesis, and point to the possibility of these rocks having been involved to some extent in the last stage of the folding movements. This conclusion serves to corroborate the petrographic evidence in favour of the Lower Devonian age of the rocks of this system.

c. The Lower Dacite Series:—

This series is associated with its successor, "The Middle Dacite Series," (*d*), by strong affinities, which place the pair in sharp contrast with the first series, (*a* and *b*), which are also closely affiliated.

This series is characterised by abundant phenocrysts of quartz, and some of felspar and biotite, all set in a glassy to crypocrystalline ground mass. The series consists chiefly of lavas, charged with fragments of this and other igneous material, and of hornfels. In the weathered sections, exposed along the railway line between Lilydale and Evelyn, this included material is well exhibited. The fragments vary from the smallest size to that of a man's head. All this points to an alternation of explosive and effusive phases, resulting in the incorporation by the lava flows of showers of fragments.

Towards the close of the series the effusive phases disappeared, and it finished with a facies that is entirely fragmental. These rocks are best developed between Montrose and Evelyn on four lofty ridges, which run out from the main Dandenong Range northwards towards Olinda Creek. They vary from a coarse agglomerate to dun-coloured lapilli, containing no visible minerals. The latter occur always higher up than the former, and were probably the last phase of the series. For convenience, these fragmentals are referred to as "The Dandenong Agglomerates." (Plate XXX., Fig. 2.)

Close to the place where the Evelyn fault crosses Olinda Creek, the upper part of this fragmental series has been faulted down to stream level, and there the agglomerate is very coarse. One fragment measured fully 12 in. in diam., and it and others were more rounded than angular. There is little doubt that this place marks a centre of eruption. This is rendered still more likely by the proximity of the hornfels, fragments of which are so numerous in the effusive facies of this series. This site is marked as a volcanic centre on the map.

Stratigraphical Relationships.—The Lower Dacite Series may be seen in a hill section about ½ mile south-east of Lilydale, Allot 29^2, superposed on the Upper Toscanite Series, (*b*), and containing numerous fragments of the latter near the junction. It is, therefore, younger than (*b*). (See Plate XXX., Fig. 1.)

If anyone starts from Olinda Creek to climb the north flank of Mt. Dandenong, he will pass up in order over the following rocks: —(1) The Lower Dacite Series, finishing with the fragmental rocks named above, "the Dandenong Agglomerates"; next, (2), the

Middle Dacite Series; and, lastly (3), the Upper or Hypersthene Dacite Series, which is the normal Dacite. (Plate XXX., Fig. 3.) No cliff section of these junctions is known, but in every instance the above order of ascent was the observed order.

It is probable that in the first instance the junctions between these series occupied about the same level east and west right along the north flank of the range, but, owing to the downthrow of the Evelyn and the Olinda faults at its north-east extremity, the Middle Dacite Series (*d*) has been depressed to form the bed of Olinda Creek at that place, and the Upper Dacite Series (*e*) is also found at a low level in the fault valley. (Plate XXX., Fig. 2.)

Petrological Character.—This is a dark, slate-coloured, compact, brittle rock, showing phenocrysts of quartz freely, felspar less so, biotite in hexagonal flakes, pyrites and garnets occasionally, and numerous fragments, mostly igneous, the rest sedimentary.

Phenocrysts consist of quartz and orthoclase, idiomorphic, generally corroded, and often brecciated owing to flow movement. The quartz is more abundant than orthoclase, the latter often shows rhombic sections, with diagonal extinction. Plagioclase is subordinate to orthoclase, is idiomorphic, and apparently ranges from oligoclase to labradorite; biotite occurs in grains and flakes, bleached, and flexed by flow movement; garnet is common, often chloritised; iron oxide is seen in irregular grains, and there is also a secondary oxide associated with and derived from the biotite; apatite and zircon are present as accessories.

The ground mass is abundant, glassy to cryptocrystalline, and lines of flow frequently are well developed, with fragments of the phenocrysts corresponding thereto. Numerous inclusions of volcanic material and hornfels are present.

Chemical Composition.—In this rock the sub-alkali character is pronounced. It is much richer in CaO and MgO, and poorer in alkalis than the toscanite series. It has over 68 per cent. of SiO_2, and is, therefore, a dacite.

For these and other reasons, which appear later, this series has been called "The Lower Dacite Series."

d.—The Middle Dacite Series.

If we regard the Dandenongs as built up of three layers, then the present series (*d*) constitutes the second layer, except at the north-east corner, where it has been faulted down to stream level. It rises, abruptly, in most cases, above the "Dandenong Agglome-

rates," and is crowned by the Upper Dacite Series, (*e*). (Plate XXX., Fig. 3.)

Compared with the Lower Series (*c*), the rock is lighter in colour, more porphyritic, and therefore more crystalline, and it contains no fragmental material. It has fewer quartz phenocrysts, but in its earlier stages more felspar (plagioclase being greatly in excess of orthoclase, whereas in series (*c*) the reverse is the case), and ferro-magnesian minerals in about the same proportion.

It is distinguished from the Upper Dacite (*e*) by its abundant quartz and felspar phenocrysts, especially the former.

Towards the top of the series, i.e., approaching its junction with the Upper Dacite, the phenocrysts of quartz and felspar become fewer and much larger. The rock also becomes darker, and acquires a certain outward resemblance to the Upper Dacite. But notwithstanding this evidence of gradual differentiation within the series, there is no difficulty, except where landslips have masked the conditions, in drawing a sharp boundary line with the Upper Dacite. The two series are quite distinct.

Stratigraphical Relationship.—Wherever this series is in contact with the series *c*, the former occupies the higher level. Wherever it is in contact with the Upper Dacite (*e*), it occupies the lower level. This general testimony of superposition indicates that the order *c*, *d*, *e*, was the order of extrusion. For reasons given later, the Upper Dacite must be regarded as the last of the volcanic system, and the above order may be taken as confirmed.

Petrological Description.—The lower type is a gray rock, showing very numerous phenocrysts of felspar, quartz, and biotite, naming them in the order of decreasing abundance. The phenocrysts consist of quartz, idiomorphic, and often corroded; plagioclase (labradorite chiefly), zoned, idiomorphic, though often fractured, and sometimes containing small inclusions of sphene; orthoclase in clear rhombic crystals, extinguishing diagonally; plagioclase in excess or orthoclase; biotite, flexed into conformity with the flow lines; and pyroxene (?) much altered, identified mainly by the boundaries, giving extinction angles of 22 deg. to 39 deg. Garnet is common; apatite and zircon not uncommon; ilmenite accessory. The glassy ground-mass is obscured by myriad fragments of the phenocrysts, fractured by flow movements, and now arranged in conformity with the well-marked flow lines.

In the upper type of this series, quartz and felspar are in fewer but larger phenocrysts; deeply zoned plagioclase is still in excess of orthoclase; garnet is less abundant, if not absent; biotite is

more fragmentary, and intensely pleochroic. There is also a micaceous dust shimmering through a ground mass composed of a granular maze of quartz, felspar, and biotite, and a glassy residue. The flexure of the biotite and the corresponding arrangement of the other fragments indicate marked flow structure. Ilmenite is still abundant.

e.—The Upper or Hypersthene, or Normal Dacite Series.

This is the last and probably the greatest series of the system. Though occupying only the upper portion or crest of the Dandenongs in the north, it extends over 10 miles south, passing beyond the Gembrook railway line as far as the granodiorite, and at the same time spreading west as far as Lower Ferntree Gully, and east to Monbulk and Emerald.

This normal Dacite is distinguished from the preceding series thus:—Its porphyritic character is much less apparent, the phenocrysts being small, while quartz phenocrysts are very seldom seen; hypersthene is very abundant, though it appears to be quite absent from the preceding series, except possibly the first. Even in the series immediately underlying the normal Dacite, I have not found one occurrence of hypersthene. Orthoclase is present, but in a much lower ratio to plagioclase.

This dacite shows no difference from the Upwey dacite described by H. C. Richards (16), except that here rutile sometimes occurs in well-formed crystals.

Schistose Dacite.—In certain places, secondary biotite has formed in clusters, surrounding the hypersthene to some extent, and the ilmenite to a greater extent. At Mt. Dandenong this alteration is not easily noticeable, but going east towards the Evelyn fault valley, it becomes more marked, and on the highest part of the hornfels ridge, that forms the eastern wall of this valley, there are a few small residual patches of schistose dacite. Of these patches, one at least is almost, if not quite, isolated by the Silurian hornfels from the main mass of the dacite of the Dandenongs on the west of the valley. Other patches run down the eastern slope of the valley into the alluvium. It is clear, therefore, that the normal dacite rests on the Silurian as a lava flow. (See Plate XXX., Fig. 4.)

Origin of the Schistose Dacite.—These patches of dacite are not all equally altered. In some of them the schistose structure is emphatic; in others, it is scarcely perceptible in hand specimens. The following reasons present themselves for attributing their condition to plutonic and hypabyssal intrusions of granodiorite:—

1. The close proximity of intrusions of granodiorite porphyry in the subjacent Silurian, at lower levels than the schistose rock, suggests that the alteration is due to these and hidden plutonic intrusions.

2. The Silurians beneath the schistose dacite have been altered into hornfels, which is an extreme product of thermal metamorphism, and it is impossible to doubt that the altered dacite must be referred to the same cause as the hornfels.

Regarding the irregularity of the distribution of schistosity that has been noted in the small area under discussion, the prevalence of the big granodiorite dykes suggests the explanation that these anomalies are due to the unequal distance of the dacite from these intrusions, and possibly also to their unequal distance from the cooling surface.

B.—The Plutonic Phase.

The dacite forms a sharp junction with the granodiorite, south of the Gembrook railway line, and for six or seven miles along the contact, the former has been converted into a band of gneiss, penetrated in several places by veins of pegmatite and quartz. For these reasons, Prof. Skeats (13), in describing the above metamorphism of the dacite, concludes that the dacite is older than the granodiorite. Corroborative evidence obtained by Prof. Skeats at Macedon, Warburton, Nyora, and Marysville, confirms this conclusion.

Comparison of the chemical analyses of the dacite and of the granodiorite has shown that they are almost identical in composition, and are therefore referable to the same source, and to the same period, (13).

C.—The Hypabyssal Phase.

In the district shown on the map, two groups of dykes stand out prominently, one along the western border of the volcanic rocks, the other along the eastern border. The former group are characteristically basic, the latter intermediate in chemical composition. For reasons given below, the former are treated as differentiated, and the latter as undifferentiated dykes.

a.—The Differentiated Dykes.

These form a group of four along the western border of the system. They all penetrate the volcanic rocks, but two of them lie outside the area of the map. They may all be called Augite Olivine

Dolerite Dykes, but they fall into two pairs owing to a marked difference in structure, viz., ophitic and non-ophitic.

The Non-Ophitic Dykes comprise a dyke lying just outside the south-west corner of the area mapped, viz., in Allot. 48, and the dyke shown off Cambridge-road in Allot 23a1. The former has a width of at least 4 to 6 feet, and was traced for 50 yards, the latter is not less than 10 feet wide, and was traced for about 100 yards.

These are dark, fine-grained basaltic rocks, with no minerals discernible in hand specimens. Augite occurs in grains through the ground mass, and in larger crystals, with frequent twinning, olivine is now represented by its pseudomorphs. Iron oxide is very abundant, with shape and lustre of magnetite, but the prevalence of leucoxene-like alteration product suggests that the rock is titaniferous, and that some ilmenite is present. Laths of plagioclase (chiefly labradorite) are common, apatite occurs sparingly. Ground mass consists of granular matter set in cryptocrystaline to glassy base.

The Ophitic Dykes comprise a dyke in Allot. 40b, and a dyke lying outside the map, where it penetrates a small residual of the series (*a*).

The former is a dark compact rock, showing large phenocrysts of augite, and long thin laths of felspar. This augite is green, generally zoned, and showing composite structure, often moulded on idiomorphic olivine, and penetrated by laths of basic plagioclase. Augite also in long purple, slightly pleochroic crystals, suggesting a titaniferous variety. Iron oxide is very abundant.

The latter is also a dark compact rock, but with much smaller crystals of augite and olivine. Its structure answers the description of the previous rock as far as the relations of augite, olivine and felspar laths to one another are concerned. But there is also an abundance of another mineral occupying interstices, mouded on the augite and olivine, and often enclosing the plagioclase laths. It has two cleavages, one perfect, is biaxial and negative, with low pol. colours, and a ref. index between 1.494 and 1.510, and does not gelatinise with H.Cl, though it is decomposed by it. It thus has the qualities of Stibite. Although it has the appearance of a primary mineral, especially as the rock shows no other signs of alteration, it certainly owes its origin to the pneumatolytic action of steam upon a ground mass whose remains are now only sparingly developed, and which was close to plagioclase felpar in its constituents and proportions.

In direction these basic dykes diverge a few degrees west of north, the divergence being greatest in the southernmost of them.

Regarding their *age*, it is difficult to decide whether they are related to the Devonian cycle or to the Tertiary basaltic eruptions. But the following considerations favour the former view :—

1. The neighbouring basalts contain no augite except in the ground mass, whereas the dykes are full of phenocrysts.

2. The close association of the dykes in each case with the Devonian igneous rocks.

3. The directions of the dykes are consistent with the hypothesis that they are part of a radiating system from some centre in the Dandenongs.

If this view be right, they must be regarded as differentiated dykes, representing possibly the complementary products of the acid lavas which appeared in the earlier part of the volcanic phase.

What appears to be a pair of complementary dykes is marked at the foot of the north slope of the Dandenongs in the Lower Dacite Series, adjacent to Olinda Creek in Allot 78. The two dykes outcrop within 10 yards of each other, but the outcrop is too limited to determine their direction.

The Basic Complementary dyke is a Dolerite. It is a bluish-black, tough, fine-grained rock, showing abundant pyrites. It contains laths and idiomorphic phenocrysts of plagioclase (mainly labradorite), and pseudomorphs of two other minerals, one apparently after a pyroxene, and showing ophitic structure, the other after olivine. Iron oxide is common, pyrites abundant, and calcite occurs in the vesicles. The ground mass is cryptocrystalline, and shows no flow structure.

The Acid Complementary dyke is a light gray porphyritic rock, crowded with phenocrysts of quartz, and streaked with small, elongated, white areas, due to the occupation of vesicles by secondary minerals. It contains phenocrysts of quartz, idiomorphic, but often corroded; orthoclase, with square or rhombic outlines and diagonal extinction; plagioclase (andes.-labrad.) ; biotite in flakes flexed in conformity with the flow lines, and often containing the sagenite web of rutite needles. Apatite and zircon in good proportions. Besides the orthoclase phenocrysts, there are also numerous orthoclases of similar shape, but of progressively smaller size, till those of the ground mass are reached, which is packed full of them.

Between Lilydale and Evelyn two dykes are visible in sections of the railway cutting, one (Allot. 26) about 20 feet wide, the other

(Allot 30[a]), 5 feet wide. Both are much decomposed, the latter being now a soft, gritty rubble. Both strike about 3 deg. west of north.

b.—The Undifferentiated Dykes.

These dykes all occur either penetrating, or closely associated with, the remains of the igneous rocks that form a broken border along the eastern side of the Evelyn fault.

They fall into two divisions: (1) the Wandin dyke, (2) the granodiorite porphyries.

(1) *The Wandin Dyke.*—This dyke lies about $1\frac{1}{4}$ miles due west of Wandin (Allot. 33[a] and 3) in the series *b*. It outcrops sporadically for $1\frac{1}{2}$ miles, and with an average width of about 45 to 50 feet. It bears a very close resemblance to the propylitized Dacite dyke of the Macedon district (one mile west of Hesket) (15). The chemical analysis of the latter is probably very close to that of the former, and has been used for that reason in the variation diagram, where it conforms very well with the curves.

This is a granitic-looking rock, with numerous phenocrysts of felspar and dark biotite, set in a fine ground mass.

There are large idiomorphic phenocrysts of zoned plagioclase, biotite, and probably another mineral now chloritised. Smaller irregular-shaped crystals of orthoclase are numerous. The rest of the rock consists of a micrographic intergrowth of quartz and orthoclase, which surrounds the phenocrysts. The plagioclase is sharply marked off from the eutectic corona, but the orthoclase often passes into it by a gradual transition. Apatite is common; zircon and magnetite are sparingly present. The granophyric structure, which is due to pneumatolytic action on the ground mass, supports Becker's suggestion, "that the ground mass of a porphyritic rock tends to approximately eutectic composition."[1]

(2) *The Granodiorite Porphyries.*—These form a group of dykes, lying west of South Wandin, on the high hornfels shoulder of the Dandenongs between Olinda Creek and the Evelyn fault. As the structure here contains several interesting features, a more particular description is given. (Plate XXX., Figs. 3 and 4.) The Evelyn fault is marked in this part by a deep depression, which develops into two valleys, one north, the other south of a small watesrshed in the depression. The dacite is sharply severed from the hornfels by these two fault valleys, except at the watershed,

1. See (19) p. 264.

where, and a little to the south of which, the Dacite is found lying on the top of the hornfels ridge, as much as 200 yards east of the fault. It differs, however, from the Dacite west of the fault in three respects :—

i. It forms residual patches on the hornfels.

ii. It is schistose, and in some cases intensely so.

iii. It is closely associated with the granodiorite-porphyry dykes which occur in the hornfels at lower levels than the schistose dacite, and which, together with the plutonic mass they represent, are responsible for the production of the schists and hornfels. A boulder of the dyke rock was found in the gneissic dacite. But whether this was an included fragment, or the head of a hidden dyke, could not be determined. The presence of other dykes tends to favour the latter view. But, in any case, it is clear that the dykes, though possibly to a small extent simultaneous with the dacite, were in the main later than it.

These dykes are mineralogically similar, but they vary in the coarseness of the ground mass from a type about three times coarser than the Dacite up to a type where the minerals of the ground mass are nearly as coarse as the phenocrysts. This latter type is developed on a very large scale in a deep valley in north-east corner of block 920^{b}.

The following is a composite description of the commonest types found.

Phenocrysts of plagioclase are abundant, quartz not so common, biotite is abundant, and subordinate orthoclase. Biotite, associated sometimes with a little muscovite, is often arranged in radiating bunches. Ground mass consists of quartz and orthoclase mainly, the latter often in square or rhombic sections, with diagonal extinction, but plagioclase, and flakes of biotite are also present. Apatite, zircon, iron oxide, and pyrite (intimately associated with biotite) are present as accessories.

Relation to the Dacite.—We may safely assume that these dyke rocks and the associated dacite were derived from the same magma basin. In the Dacite, the ground mass contains quartz and felspar in proportions of about 20 per cent. to 13 per cent. (16). In the dykes, this quartz and felspar form crystals whose size increases as the rock becomes more hypabyssal, until a type is reached where it is hard to distinguish the crystals of the second generation from those of the first. It, therefore, appears that the only true phenocrysts in these dykes, and possibly in the deeper-seated plutonic rock also, are the more basic felspars, some of the quartz and biotite, and

the accessories. The hypersthene, which is practically confined to the dacite or superficial rock, and even then is unstable in the presence of heat, changing over into biotite, is probably not a true phenocryst, but a crystal of the second generation, resembling, in this respect, the olivine of basalts,[1] which attains such a size owing to its power of spontaneous crystallisation, and to its rapid rate of growth.

Other undifferentiated dykes, viz., hornblende porphyrite, found by Prof. Skeats (13) near Aura, both in the granodiorite and in the dacite, are regarded by him as "genetically connected with the granodiorite, and as forming one of the later incidents connected with the plutonic rock."

The dykes marked on the map show indications of a radial arrangement with reference to some centre in the Dandenongs. Further observation of dykes on the south-west and south-east flanks of the Range are needed to be certain about it.

D.—The Volcanic Succession.

The following rock analysis have been made through the kindness of Mr. E. J. Dunn, by the officers of the Geological Survey Laboratory :—

	A	B	C	D
SiO_2	68.19	69.93	68.73	65.83
Al_2O_3	14.98	15.14	13.16	14 89
Fe_2O_3	0.74	1.30	1.17	0.73
FeO	2.74	2.33	2.74	4.63
MgO	0.29	0.26	1.22	1.88
CaO	1.95	1.80	3.03	3.13
Na_2O	3.34	3.36	2.30	2.12
K_2O	3.64	3.55	2.59	2.32
H_2O	1.40	0.83	1.86	2.41
$H_2O = (100°C)$	0.14	0.07	0.09	0.17
CO_2	1.93	nil	1.50	0.47
TiO_2	0.20	0.20	0.50	0.89
P_2O_5	0.05	0.03	0.17	0.16
Cr_2O_3	nil	nil	nil	trace
MnO	0.08	0 05	0.09	0.10
NiO	nil	nil	0.01	0.01
CoO	nil	nil	nil	nil
BaO	0.27	0.30	0.20	0.13
Li_2O	nil	trace	trace	nil
S	trace	trace	0.18	0.10

1. See (19) p. 218.

	A	B	C	D
SO_3	nil	nil	nil	nil
Cl	trace	trace	trace	trace
Total	99.94	99.15	99.54	99.97
Less O	—	—	.07	.04
Total	99 94	99.15	99.47	99.93
Sp. Gravity	2.652	2.658	2.687	2.702

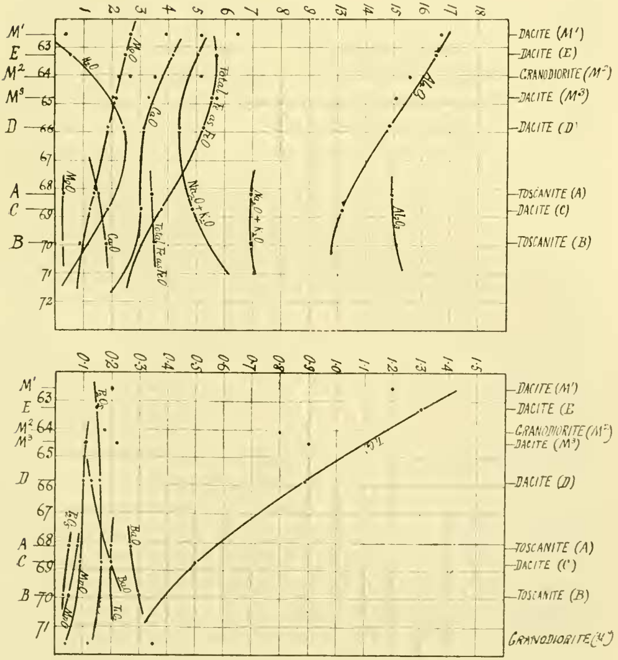
A. Lower Toscanite. Specimen from quarry 1m. N.E. of Lilydale, allot. 24, N. end.

B. Upper Toscanite. Specimen from quarry about 1m. E. of Mooroolbark, allot. 22c.

C. Lower Dacite. Specimen from railway cutting between Lilydale and Evelyn, allot. 30c.

D. Middle Dacite. Specimen from Dandenong Range, N.E. flank.

Fig. 1.



Taking Richards' analysis (16) of the Hypersthene Dacite at Upwey, in addition to the above four, we are thus provided with a complete set, representing each of the five volcanic series. The variation diagram has been prepared from these analyses, and I have also introduced analyses of the following closely-related dacitic rocks of the Macedon district, described by Skeats and Summers (15), viz:—

M^1, Dacite, Braemar House.

M^2, Granodiorite, Braemar House.

M^3, Dacite, Hesket.

M^4, Grandodiorite, Baringo.

The petrological affinities of the Macedon and the Dandenong districts are indicated by the conformity of the analyses of the former with the curves of those of the latter, as far as the three Dacite Series (*c*, *d* and *e*) are concerned. These all form a serial group. The two toscanites (*a* and *b*), however, fall together on curves of their own. It is, therefore, obvious that either they have pursued an independent line of differentiation in the same cycle, or else, that they belong to some period older than the dacites.

In the absence of other evidence, I have preferred the former view for the following reasons:—(1) The distribution of *a* and *b* is such as to keep them everywhere in the closest association with the three other series. (2) The chemical analyses show family characteristics between the two groups, e.g., they both have a very high percentage of BaO, indicating probably a barium felspar throughout the four series; further, the series all fall in or near the sub-alkali division.

Order of extrusion.—The variation diagram shows that *a* and *b* form an inseparable pair. For reasons set forth earlier, *a* is regarded as being older than *b*; *c* has been found superposed on *b*. This gives us the order, *a*, *b*, *c*. For the reasons given below, *e* must be regarded as the last, and *d*, the penultimate, series of the cycle. Therefore, the order must be *a*, *b*, *c*, *d*, *e*, and this is the order which is everywhere indicated by the evidence of superposition.

Magmatic differentiation.—There appears to be little doubt that these five series, excepting possibly the toscanites, are consanguineous. They are, therefore, regarded as the differentiation products of a primordial magma, which there are the following reasons for believing to have had a chemical composition, similar to that of the Upper or Hypersthene Dacite Series (*e*), and the Granodiorite, and the Wandin Dyke:—

1. The above three rocks represent respectively the volcanic,

plutonic, and hypabyssal phases of the cycle, and they occurred in that order. The chemical composition of these three types is practically the same. It is clear, then, that after the extrusion of the first four series of the volcanic cycle, the magma remained unchanged, not only throughout the last series of the volcanic phase, though that series probably exceeds in magnitude all the previous ones added together, but also throughout the plutonic and hypabyssal phases to the end of the cycle.

2. These three types also bear the same relationship to one another in the Macedon district, where no differentiated rocks of the dacite family have been found.

3. There are immense developments of normal dacite, sometimes associated with granodiorite, in the neighbouring mountains between Healesville and Warburton, the Black's Spur, and the Cerberean Ranges.

With these reasons for regarding the Upper Dacite as representing the undifferentiated magma, there remain but four volcanic series which are differentiated, viz., *a*, *b*, *c*, and *d*.

By both mineralogical and chemical evidence these four series are resolved into two pairs. In the first pair (*a* and *b*) quartz is absent, except in the ground mass. In the second pair (*c* and *d*) it is abundant. In the variation diagram, the second pair fall with the Upper Dacite (*e*), the Granodiorite, and the Wandin Dyke, on the same curves. But the first pair fall on separate curves, being richer in SiO_2, Al_2O_3, and alkalis, but poorer in oxides of Ca, Mg, and Fe, than the second pair.

It thus appears that, if the toscanite be admitted to this cycle, there must have been an early separation of the magma into two parts.

One of these redivided, forming two magmas (*a* and *b*), almost identical in chem. composition, except that *a* was much richer in H_2O than *b*, with the result that though chemically similar, they are mineralogically different.

The other part, which was richer in basic constituents, and though poorer in SiO_2, contained much free quartz, divided into two series (*c* and *d*), such that the latter, containing more of the basic constituents, and more water, produced a rock more crystalline than the former, and containing less quartz, but more felspar and ferro-magnesin minerals.

Examples of the differentiation of andesitic magmas have been described by Judd (21), and by Teall and Lagorio. The latter observers remark that the order of crystallisation is such that the

magma becomes progressively more acid. In the Dandenongs, however, the order of extrusion was progressively less acid. This order is also exemplified in the Buchan district (12), where the L. Devonian igneous activity opened with quartz porphyries and rhyolites, and closed in some cases with andesites.

e.—Nomenclature of the Igneous Rocks.

There can be no doubt that a true classification ought to be genealogical, and it should also provide a nomenclature that would make it possible to give a generic name to all the members of any family of rocks, which have been produced by modification during descent from the same parent magma.

If we accept Hatch's classification, as it stands, then, in the case before us, the plutonic rock of the Belgrave railway line is too poor in SiO_2 [63.85 per cent. (Richards), and 64.41 per cent. (Plant)] to be called a granodiorite.

Further, taking the five volcanic series, the Upper series, hitherto called the "Hypersthene Dacite," would be the only one of the five which was not a dacite. No analysis has appeared, where its SiO_2 rises to 66 per cent. But, as all these series belong to one family, and that of obvious dacitic character, Hatch's boundary line should be elastic enough to enable us to give them all the same family name. Series *e* is therefore called the "Upper Dacite Series."

The first two series, containing nearly 7 per cent. of alkalis, and nearly 70 per cent. of SiO_2, form a pair of alkali dacites. As the ground mass of the first is full of orthoclase, while that of the later is microcrystalline, I proposed at first to name them respectively, "Orthoclase Alkali Dacite Series," and "Microcrystalline Alkaline Dacite Series." For the sake of simplicity, however, I have called them "The Lower," and "The Upper Toscanite Series," in conformity with the existing classification, though there is nothing in those names to indicate any consanguineity of these with the remaining three series.

In view of these two toscanites (alkali dacites), in which no quartz is to be seen except in the ground mass, where it is not greatly developed, it seems inadvisable to place too much reliance on Hatch's rule that dacites are mineralogically distinguished from andesites by the presence of quartz.

The last three volcanic series have been named for simplicity, "Lower," "Middle," and "Upper Dacite Series" respectively.

V.—Faults.

The map shows a narrow band of the series *b* along the western edge of the system, between the silurian, with which it forms a broken border on the west, and the series *c*, with which it forms a very regular junction on the east. This latter junction has such uniform persistence in direction over a course of seven miles, as to need explanation, especially as it is matched about two miles to the east by another very uniform, though arcuate boundary, which marks the eastern limit of the igneous system, and is for a large part of its course parallel to its western fellow.

Of these two junctions three explanations present themselves. They are either—

1. Natural boundaries, or,
2. Fold junctions, or
3. Fault junctions.

1. The first fails to explain in the case of either of them the uniformity of direction over a long distance, which contrasts so conspicuously with the many indisputable natural boundaries in the map. And when the two cases are taken together, its inadequacy is still more apparent.

2. Regarding the second, it has been shown that these igneous rocks lie unconformably on the upturned edges of the Silurians. If, therefore, the igneous rocks were involved in the folding processes, it can only have been to a small extent, so small that the resultant folds would be too shallow to account for the uniform junctions in question.

3. The evidence points strongly to the view that they are fault junctions. I have, therefore, interpreted them from this point of view, referring to the western junction as the Montrose fault, and the eastern one as the Evelyn fault.

The Montrose Fault.—This junction has been mapped for seven miles from the Salvation Army farm near Bayswater to Lilydale, and, excepting a small bulge westward, between Montrose and the Olinda Creek, its course throughout may be represented by a line which is very regular and persistent in direction. The junction is not visible all the way, but wherever it can be seen, it conforms to this line.

The series *b*, which lies along the west of the junction for the whole distance, may be seen outside of Lilydale, on the east of the junction, underlying the series *c*, which also contains many included fragments of it at its base. It follows, therefore, that if

the fault exists, the downthrow must have been on the east, where the younger rock, viz., series *c*, is preserved.

The Evelyn Fault.—The Montrose fault, which skirts the western wall of the Dandenongs, is matched along the eastern wall by another junction, which marks the igneous rocks off sharply against the silurians on the east. This junction passes Evelyn about half a mile to the east. From this point it runs a little east of north, keeping parallel with the Montrose fault, two miles away to the west, and like it, separating the series *c* on the west from series *b*, or, where this has been denuded away, from the Silurians, on the east. Tracing it south from Evelyn (Plate XXX., Figs, 4, 5), it ends abruptly at the Olinda Creek, but starts again some 250 yards to the east, whence it runs in a direction a little west of south, cutting across the eastern shoulder of the Dandenongs, and severing dacite from hornfels. After trending about half a mile in this manner, it bears east again, and recovers a course which would conform with the arcuate continuation of the junction, if it had crossed Olinda Creek directly. It therefore appears to have been faulted out of its path at the Olinda Creek.

The path of the junction across the Dandenongs is marked by a deep depression, referred to in this paper as the Evelyn Fault Valley. For half a mile south of Olinda Creek, this depression is steep and narrow. (Plate XXX., Fig 4a, Sect. AB). Further south, it forms an equally deep but very broad valley, the two valleys being separated by a small watershed in the depression. (See Fig. 4a, Sect. CD.) The broad valley opens out southward upon the upper course of Olinda Creek. I have not traced the junction south of this point, but on consulting a map of the Woori Yallock basin, by J. Easton, whose map practically begins where mine ends, it appears that if this line is continued in the same direction to Monbulk, it will still mark off the dacites on the west from the silurians on the east. On the other hand, if the junction were continued at its northern extremity, across the Yarra, it would pass along the eastern wall of the western pair of quartzite ridges described earlier. (Plate XXX., Fig. 5.) The Stringy Bark Creek, on crossing this junction in its north-west course, is immediately lost in a wide marsh. The Yarra also, on crossing the place where this junction would occur, expands into an extensive marsh on the left bank.

Here then is a line separating various kinds of rock, and yet maintaining a uniform arcuate direction for many miles. Evidence of depression on the west of it exists at Olinda Creek. (Plate

XXX., Fig. 2), and also, if we regard it as continued to the Yarra, in the two marshy areas above referred to. The theory that it is a normal junction, though satisfactory for section CD, across the Fault Valley above referred to, appears to be inconsistent with section AB, where the valley is not broad, but deep and narrow, the junction being nearly vertical. The fault theory is therefore supported, not only by the persistence of direction, and the evidence of depression on the western side, bot also by the nature of this valley, which I have therefore called the "Evelyn Fault Valley."

The downthrow of this fault would be, of course, on the west, where the younger rocks are in every case preserved.

Taking the combined high probabilities of the Montrose, and the Evelyn faults, it is difficult to avoid the conclusion that a large rectangular block, including at least the northern part of the Dandenong mountains, has foundered between these two fault planes. (Plate XXX., Figs. 1 and 3.)

Some six months after I had mapped the northern part of the Montrose fault, Mr. J. T. Jutson published his valuable paper on the Physiography of the Yarra (18). He postulates, though, with a query, what he calls the Dandenong fault, running along the western edge of the Dandenong Range, in the path of the Montrose fault, and continuous in the south with the fault discovered by Sir A. R. C. Selwyn, near Frankston (18). He also continues the Brushby Creek fault southwards in the same manner. Between these two fault planes, he believes, a block has been relatively depressed, producing in the South the Carrum Swamp, and a portion of Port Phillip, and in the north, the Croydon Senkungsfeld.

The fresh evidence educed in this paper points to the need of certain modifications of this theory:—

The Croydon Senkungsfeld has been relatively depressed, as he says, against the Brushy Creek fault scarp, but not against the Dandenong Mountains. On the contrary, if the senkungsfeld extends so far east, then the Dandenongs have been faulted down against the senkungfeld. Since the relative depression occurred, not on the west of the fault plane, as Mr. Jutson has postulated, but on the east, the Dandenongs possess their present height, not because of these dislocations, but in spite of them. For this reason I am unable to agree with Mr. Jutson's theory of a Dandenong fault, forming the eastern boundary of the Croydon Senkungsfeld.

Seeing that there is very probably at least one fault (Montrose fault), coasting the western wall of the Dandenongs, it remains to

consider whether, although it be the reverse of what Mr. Jutson postulated, it may not, as he believes, by a northern continuation of Selwyn's fault. If it may, then we must imagine a see-saw movement on an east and west axis, south of which, if the beds were depressed, then north of it they must have been elevated, and vice-versa.

Now, this see-saw movement could have occurred on the east of the fault pane, or on the west of it. It did not occur on the west of it, for the senkungsfelder in the north, and the Carrum Swamp in the south, indicate a depression at both ends of the block. It can only have occurred, therefore, if it occurred at all, on the east of it, the sinking of the Dandenongs in the north being balanced in the south by a rising of the granitic areas of Mornington peninsula.

The presence of the small basalt-capped plateau lying west of Cave Hill, Lilydale, suggests the possibility of its being the eastern boundary of the Croydon Senkungsfeld. In this case, if the boundary were determined by a fault, that fault would lie one and a half or two miles west of the Montrose fault.

The Olinda Fault.— It has already been noted that where the Evelyn fault meets Olinda Creek, it appears to have been heaved out of its course about 250 yards to the east, with the result that the series *d* is now found at the foot of the high cliffs of hornfels and series *c* on the north bank of Olinda Creek, which occupies the junction. (Plate XXX., Fig. 4.) The existence of this Olinda fault is supported by all the evidence in favour of the Evelyn fault. If, therefore, the latter be taken as established, the former must be also. The downthrow was on the mountain side, where the igneous rocks are preserved against the silurians.

Above the Evelyn fault, the Olinda Creek valley is very young. It is marked by rapids and waterfalls, the latter having receded more than one mile above the fault. Below the fault the valley widens, so that the stream meanders through wide alluvial flats. This rejuvenation of the stream has probably resulted in its capturing much of the headwaters of Stringy Bark Creek.

VI.—The Tertiary Igneous System.

I have taken Stirling's boundaries for the basalt. The basalt lies upon the silurians, capping a small plateau west of the railway line, between Lilydale and Mooroolbark. At Cave Hill it occupies an old river channel, whose sands lie between it and the limestone.

Here it is limited by the quartzites, which evidently formed the eastern bank of this channel. It nowhere transgresses the igneous rocks of the Devonian cycle to the east, which probably formed high ground when the basalt was poured out.

Macroscopically, it is a dark, non-vesicular, very tough, fine-grained rock, with small crystals of green olivine.

Microscopically, olivine is abundant in large, regular crystals, and a few large laths of a basic plagioclase are set in a ground mass, composed of felspar laths, lath-shaped augite, granular olivine, and abundant rectangular magnetite, and interstitial glass.

The reference of this basalt to the older or newer series is by no means easy. Petrologically two criteria are used, viz. :—

Both tests are inconclusive, but they tend to place the Lilydale basalt in the older series. In the quarry north of Cave Hill, in allot. 30 1, the basalt is very decomposed. Added to this, the extensive circumdenudation, which is apparent, tends to favour the older age.

Source.—Till now, no undoubted vent of the older basalt has been found. At Lilydale, in the basaltic plateau, just referred to, there is a crater-like depression breached towards the north-east, which being regarded as a vent by the residents, is therefore known as "Crater Hill." Sections on the adjoining roadside resemble tuffaceous deposits. On the opposite side of the road, there is another larger depression opening on the north-west side. In a hole sunk in the bottom of this basin to a depth of about thirty feet, the basalt is present all the way. The rock on the rim of the basin has all the appearance of a decomposed fragmental rock. Further evidence is needed, before concluding that the place was an eruptive centre.

In conclusion, I wish to thank Professor Skeats, who has discussed the problems with me from time to time, both in the field and in the laboratory; also Mr. H. J. Grayson, for kindly preparing the micro photographs, and some very thin rock sections; and also Mr. E. J. Dunn, who permitted me to have four rocks analysed by Messrs. Bayly and Hall, in the geological Survey's laboratory.

VII. Summary.

The following are the most important new results contributed in this paper :—

1. The district between Lilydale and Mount Dandenong has been mapped petrologically for the first time, with the exception of the

narrow strip from Lilydale across Cave Hill, which was done by V. R. Stirling. Some of his boundaries, and those of the geological map of Victoria, published by the Geological Survey Department, have undergone important alterations during revision.

2. A denuded synclinal fold of the Yeringian (U. Sil.) series forms the basal rock of the district. Their strike is normally north and south, but in the area north-east of a line joining Lilydale and Evelyn, it is diverted 40 deg. or 50 deg. to the east.

The prevalence of littoral facies probably marks the close of the silurian invasion.

The alteration of some facies into quartzite has been caused, not by thermal metamphorism, but by metasomatic processes, aided probably by folding stresses.

3. Upon this sedimentary floor, lies a stack of igneous rocks, which have been linked up into one system with those of the Dandenong Ranges.

These rocks are regarded as representing the volcanic phase of an igneous cycle, which was completed by plutonic and hypabyssal phases.

Representative specimens selected from the three phases have been described and compared.

The volcanic rocks are resolved into five series, and these series are regarded as being consanguineous.

The chemical composition of the first four series was determined by means of analyses specially made by Messrs. Bayly and Hall.

Variation diagrams have been made from these and other analyses of rocks, selected from each of the three phases of the cycle.

The bearing of this evidence on the differentiation of the parent magma is discussed. The differentiation was progressively less acid.

The composition of the parent magma of the differentiated volcanic series is shown to be represented by the last series of the phase (viz., Hypersthene Dacite), which remained on the whole unchanged throughout the plutonic and hypabyssal phases of the cycle. It was sub-alkali, and between acid and intermediate in composition.

Of the volcanic series, the first four, which are differentiated, fall naturally into two pairs :—

(i) A pair of toscanites (or alkali dacites). These are chemically identical, but mineralogically dissimilar.

This difference is attributed to mineralisers (especially H_2O), present in the Lower, but absent from the Upper.

(ii.) The second pair have a sub-alkali composition; and are named Lower and Middle Dacite Series respectively. They differ chiefly in the ratio of ground mass to phenocrysts.

The Middle Series was followed by the Upper or Hypersthene Dacite Series, which brought the volcanic phase to an end.

All the rocks of the system, except the two toscanites, conform to the same serial curves in variation diagram. The toscanites fall on curves of their own. The question is, therefore, raised, whether they should be admitted to the cycle, or referred to some earlier date.

Evidence is presented for the sites of two eruptive centres, which are marked on the Map.

Evidence of foliation in the two toscanites, together with its absence from the remaining series is discussed especially with reference to the Devonian folding movements.

The dykes are of two kinds, differentiated and undifferentiated. There are signs of radial groupings with reference to some centre in the Dandenongs.

The undifferentiated dykes appear to be closely associated with the plutonic rock, which occurs, on the one hand, about one mile south of the Belgrave railway line, where it outcrops extensively, and, on the other hand, on the eastern shoulder of Mt. Dandenong, where it is invisible. In both cases it has converted the contiguous dacite into a schistose type, and in the latter case, it has also converted the Silurians into a hornfels, and has sent out large apophyses, which outcrop in the hornfels below the schistose dacite.

This residual patch of schistose dacite, resting upon the hornfels is clear evidence of the volcanic nature of the Hypersthene Dacite.

The type of alteration here is similar to that, described by Prof. Skeats, in the district south of Upwey and Belgrave.

"The Wandin Dyke" shows a type of propylitization similar to that near Hesket (Mt. Macedon), and described by Skeats and Summers.

In a dolerite dyke near Mooroolbark the ground mass has been secondarily altered to stilbite.

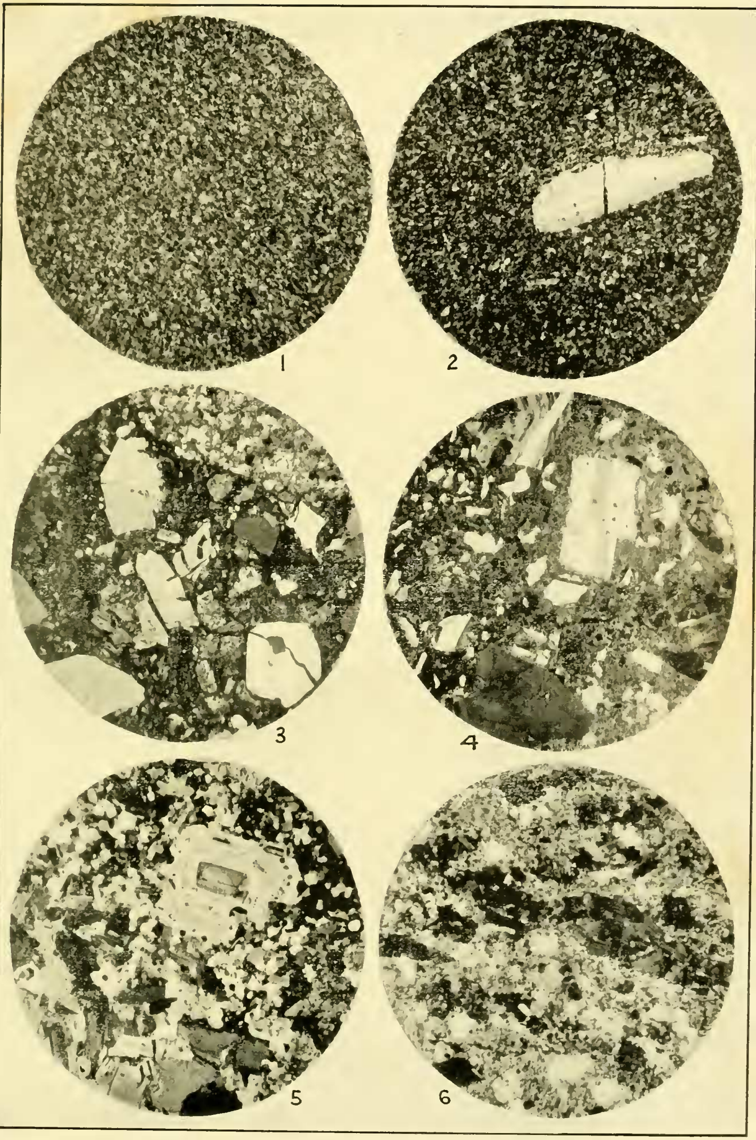
4. Evidence is discussed for placing a fault along each of two long uniform junctions, running parallel (N.E. and S.W.) for some distance, one east, the other west, of the Dandenongs. There seems little reason to doubt that a great block, including the northern part of the Dandenongs, has subsided between these two fault-planes. Evidence is presented for another fault—the Olinda fault.

5. The influence of these faults on the physiography of the district is described.

6. The tertiary basaltic eruptions are represented by a patch of olivine basalt, capping a small residual plateau about one mile west of Lilydale. This rock is described, and its age is discussed.

VIII.—Bibliography.

1. Selwyn, Sir A. R. C. Geol. Surv. Vic., Report 1856, Votes and Proc. Leg. Coun., Vic., 1855-6, Vol. ii., Pt. 1 (Map and Section).
2. Creswell, A. W. The Victorian Naturalist, 1885, Vol. ii., P. 33.
3. Creswell, A. W. Proc. Roy. Soc. Vic., 1892, Vol. v. (New Series), P. 38-44.
4. Creswell, A. W. Proc. Roy Soc. Vic., 1893, Vol. vi., P. 156-159.
5. Danvers-Power, F. Notes on the late landslip in the Dandenong Ranges, Vic. A.A.A.S., Vol. ix., Hobart (1892) Mtg., P. 337.
6. Griffiths, G. S. The Geology of Melbourne, A.A.A.S. Handbook of Melb. (1890) Mtg., P. 38.
7. Murray, R. A. F. "Geology and Physical Geography," 1895 Edn., Pp. 22-3, 33, 36-7, 43-7.
8. Stirling, V. R. "Geol. Rep. on Lilydale District." Geol. Surv. Vic. Monthly Prog. Rep. No. 1. (New Series) 1899. Pp. 10-11 (with map).
9. Gregory, J. W. "Geology of Mt. Macedon." Proc. Roy. Soc. Vic., 1901, Vol. 14, Pp. 209-221.
10. Gregory, J. W. "The Heathcotian—a preordovician series." Proc. Roy. Soc., Vic., 1902, Vol. 15, P. 170-173.
11. Jenkins, H. C. Report of the Government Metallurgist for the year 1901. Ann. Rep. of Sec. for Mines, Vic., for year 1901, P. 37.
12. Skeats, E. W. "The Volcanic Rocks of Victoria." A.A.A.S., Vol. xii., Brisbane Mtg., 1909.
13. Skeats, E. W. "Gneisses and Dacites of the Dandenong District." Quart. Journ. Geol. Soc., Vol. lxvi., 1910, Pp. 450-469.
14. Skeats, E. W. "On the Gneisses and Altered Dacites of the Dandenong District (Victoria) and their relations to the Dacites and Granodiorites of the area. Geol. Mag. Dec. v., Vol. vii., P. 134, 1910.


1
2
3
4
5
6